Future Internet Management R&D Trends: State-of-the-Art

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Topics

- Current Management Introduction & Issues
- A Way Forward: Network and Service Management R&D for FI
  - R&D Status in US
  - R&D Status in Europe
  - R&D Status in Japan
- A Way Forward: Our Approach

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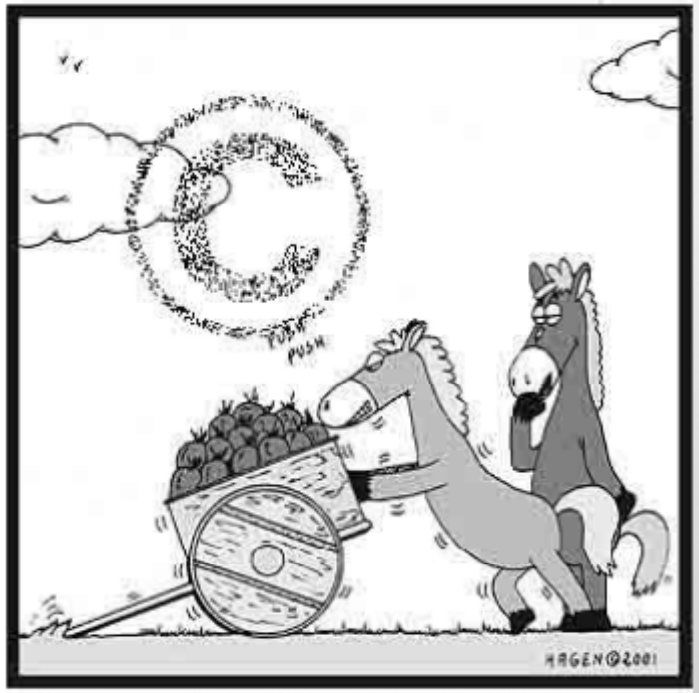
  - R&D Status in Europe
  - R&D Status in Japan
- Way Forward: Our Approach

Current Management

- Current Internet Management
  - OSI, TMN, IETF, and others were defined *after* the network functions that were to be managed were implemented
  - The Internet is evolving *past* its architectural capabilities
- No standard management architecture and language exists



Hang on... We must be doing something wrong...
How does the saying go again?

Source: John Strassner, WCU, Postech

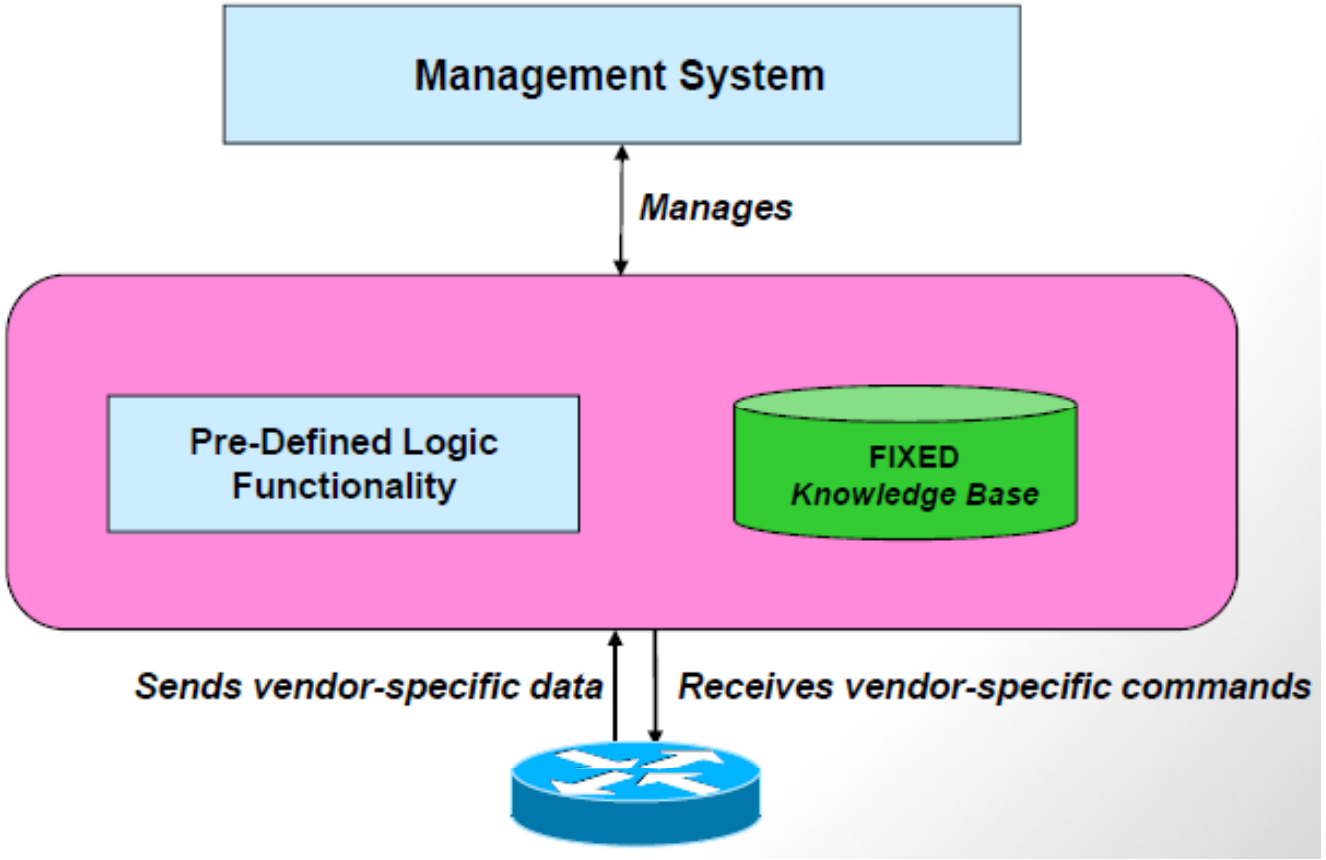
Current Network & Service Management

- Traditional FCAPS
  - Fault Management (root cause analysis, event correlation, …)
  - Configuration Management (Topology, Inventory, …)
  - Accounting Management (Usage collection, …)
  - Performance Management (Traffic monitoring, …)
  - Security Management (Access control list, key management, …)
- Improved Management Capabilities
  - Policy-based management
  - Web-based management
  - SLA management
  - Business management (accounting, charging & billing, …)
- Management & Control Plane ride on Data Plane
  - Security concerns
  - Bootstrapping problem
  - Poor failure mode operation

Service Provider Centric / Device Oriented

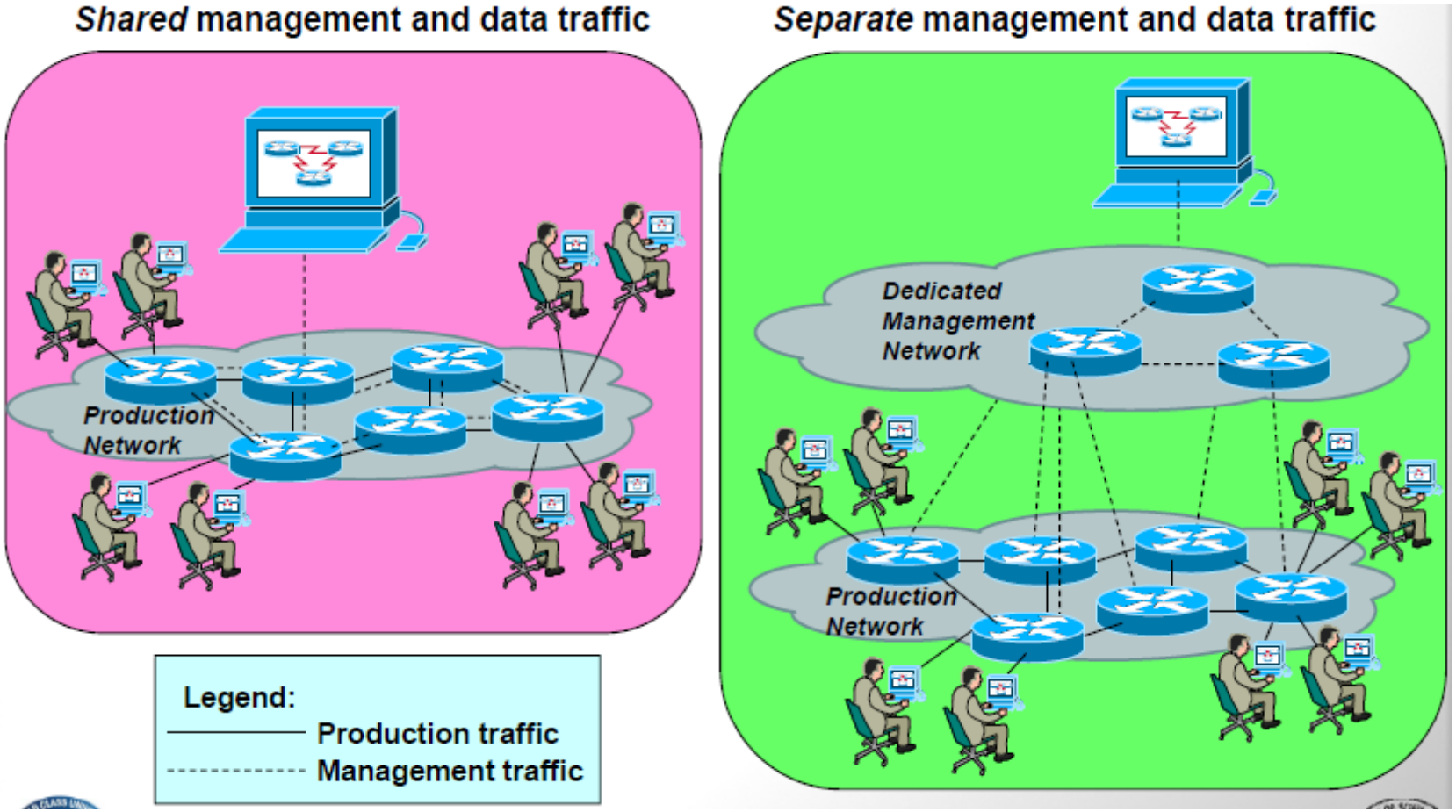
Network and Service Management

Typical Current Management Approach



Source: John Strassner, WCU, Postech

Typical Management Networks



Source: John Strassner, WCU, Postech

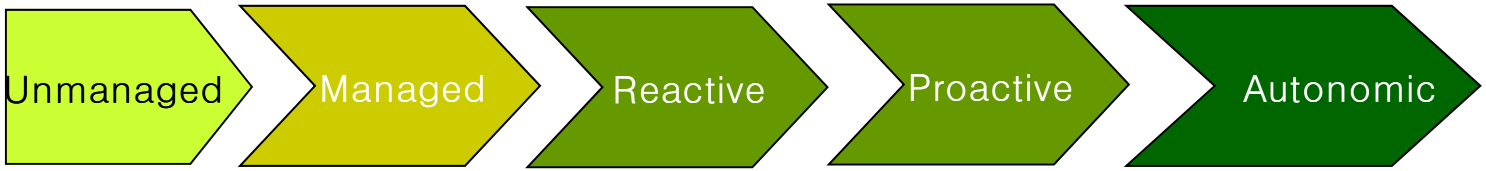
Current Management Limitations

- Network Infrastructure is developed and deployed first
  - Management and Security Capabilities are added separately later
  - Capabilities needed management can’ t be designed or tested until management is added
  - No opportunity to simulate or test before deployment
- Lack of vendor/technology neutral models and APIs
  - Logical management approach cannot be designed beforehand
- Inability to incorporate new and changed information
- Inability to customized services offered according to business and environmental conditions/constraints

Source: John Strassner, WCU, Postech

What are New Challenges for Future Internet?

- Fast
- Ubiquitous
- Huge number of service objects (users, various smart devices, applications, sensors, etc.)
- Virtualized Network & Service Infrastructure
- Service Oriented Architecture & Prosumer Active Participation
- QoS, especially QoE becomes norm
- SLAs among various entities (customers and new types of providers)
- Venerability to the anomalous attacks will increase due to the complexity of the infrastructure



Customer Centric / Service Oriented

Network and Service Management

Key Requirements for FI Magement

- Security and Reliability in a highly distributed FI environment
- Management functionality at Modeling and Design phases
- Management of Virtualized network and service resources
- Mapping of Management information into Business needs
- Separation of Data, Control, and Management planes
- Common Intelligence for management
- Standardized abstraction of management information
- Cross administration domain management

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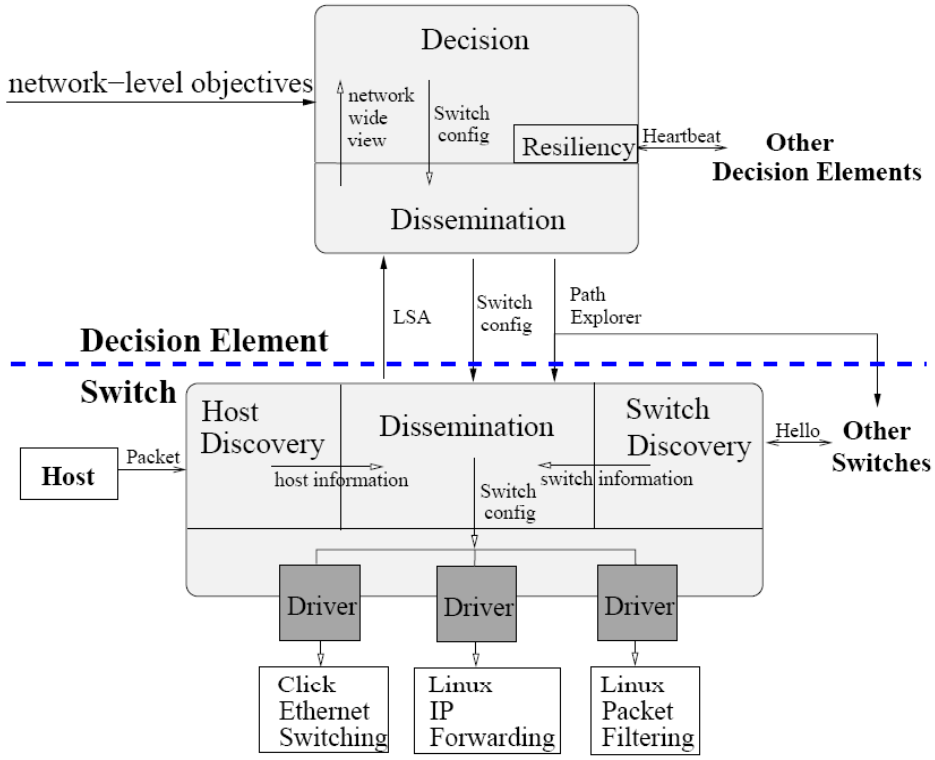
Research Efforts in the US – FIND Projects

- **4D Architecture**
  - Completely centralized approach
  - mostly addresses the routing related management issue within a AS
- Discovery Plane: Responsible for automatic discovery of the network entities
- Dissemination Plane: Based on the discovery plane data a dissemination channel is created between each network node and the Decision elements.
- Decision Plane: The centralized decision elements which compute individual network entity state (e.g., routing tables for routers etc.) based on whole network topology and policies
- Data Plane: responsible for handling individual packets and process them according to the state that has been output by the decision plane
- **Pitfalls**: scalability due to discover & dissemination broadcast –> DHT algorithm

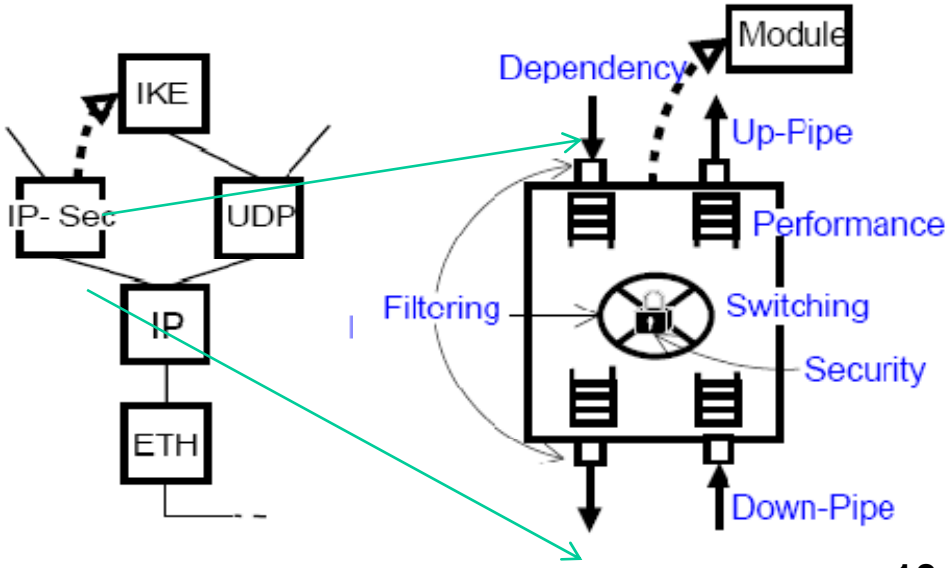


Research Efforts in the US – FIND Projects

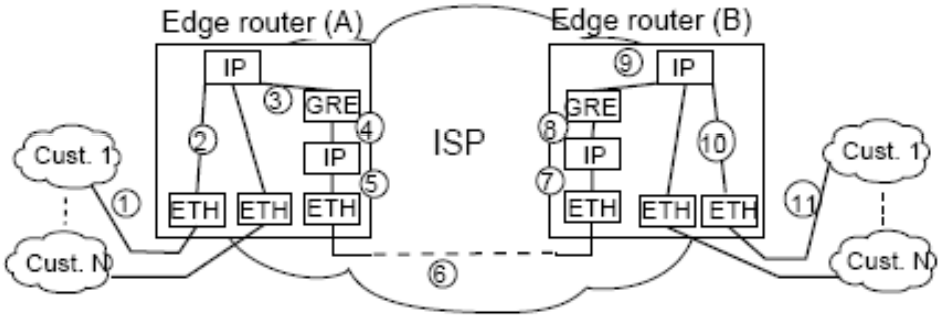
- **CONMan (Complexity Oblivious Network Management)**
  - Extension of 4D architecture
  - Reuse Discovery and Dissemination mechanisms and allow Multiple Decision elements (Network Managers)
  - Net Managers has its own management tasks besides Routing related Mgmt, thus more general than 4D

- CONMan Objectives
  - Self-configuration: less error-prone
  - Continual validation: ensures network states according to the objectives
  - Regular abstraction: uses standardized abstract management interface
  - Declarative Specification: declare the objectives in high-level abstract terms and defines automation of mapping them into low-level implementation

CONMan takes a less extreme measure than 4D by **centralizing the configurability of the network at the granularity of module interactions** rather than centralizing the whole control and management plane.



CONMan : GRE-IP Tunnel Setup Example



Configuration at router A

"Today"

```
#!/bin/bash
# Inserting the  GRE-IP kernel module
insmod /lib/modules/2.6.10-1/ip_gre.ko
# Creating the GRE module with the appropriate key
ip tunnel add name greA mode remote 128.84.223.112 local\
128.84.222.111 ikey 2001 okey 1001 icsum ocsum iseq oseq
ifconfig greA 192.168.1.3
# Enable routing
echo 1 > /proc/sys/net/ipv4/ip-forward
# Create IP routing state from customer  to tunnel
echo 202 tun-1-2 > /etc/iproute2/rt_tables
ip rule add iff eth0 table tun-1-2
ip route add default dev greA table tun-1-2
# Create IP routing state from tunnel to customer
echo 203 tun-2-1 > /etc/iproute2/rt_tables
ip rule add iff greA table tun-2-1
ip route add default dev eth0 table tun-2-1
```

Configuration at router A with

"CONMan"

```
create (pipe-2)
create (pipe-3)
create (switch-state,pipe-2,pipe-3)
create (pipe-4)
create (pipe-5)
```

(c,d)

(a)

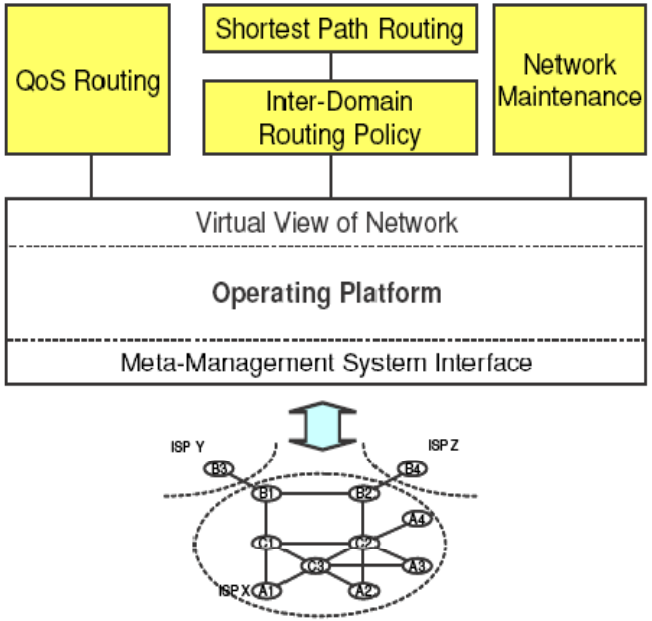
(b)

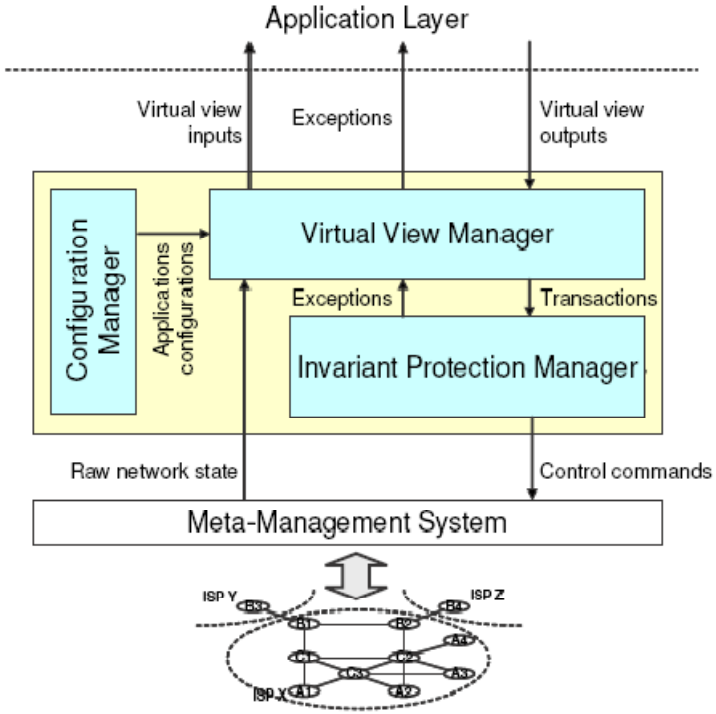
NOTE: create (switch-state,pipe-2,pipe-3) creates IP module switch state to switch from pipe-2 to pipe-3

Research Efforts in the US – FIND Projects

- **Maestro: An Architecture for Network Control Management**
  - Operating system like approaches for network control and management
  - Network controls are implemented as applications over an operating environment
  - The operating environment provides support to the network control applications by providing services such as, (1) scheduling, (2) synchronization, (3) inter-application communication, and (4) resource multiplexing

while the 4D architecture treats the control and management functions as one single monolithic entity, Maestro treats them as an aggregate of multiple functions, with an operating environment and network-level invariants ensuring synchronization among the functions and validating their outputs





Research Efforts in the US – FIND Projects

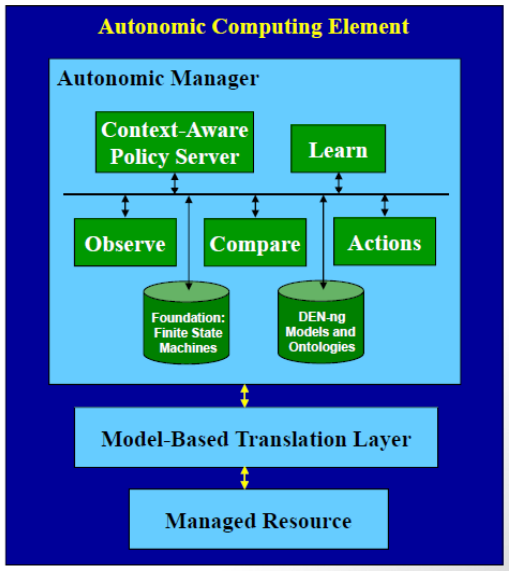
- Knowledge Plane
  - David Clark, SIGCOMM 2002
  - Requirements to collect Global network behavior and make inference for control, error recovery and management
    - Arguing against Internet Prinicple: Dumb network/intelligent edge
  - Key Attributes
    - Edge involvement
    - Global perspective
    - Composition structure
    - Unified approach : single, unified system with common standard
    - Cognitive framework
      - Representation, learning, and reasoning that allow the knowledge plane to be "aware" of the network and its actions in the network
  - Knowledge Plane Application
    - Network Fault Auto Detection and Diagnosis
    - Fault Auto Recovery or Root Cause Identification
    - Requirement based automatic (re)configuration

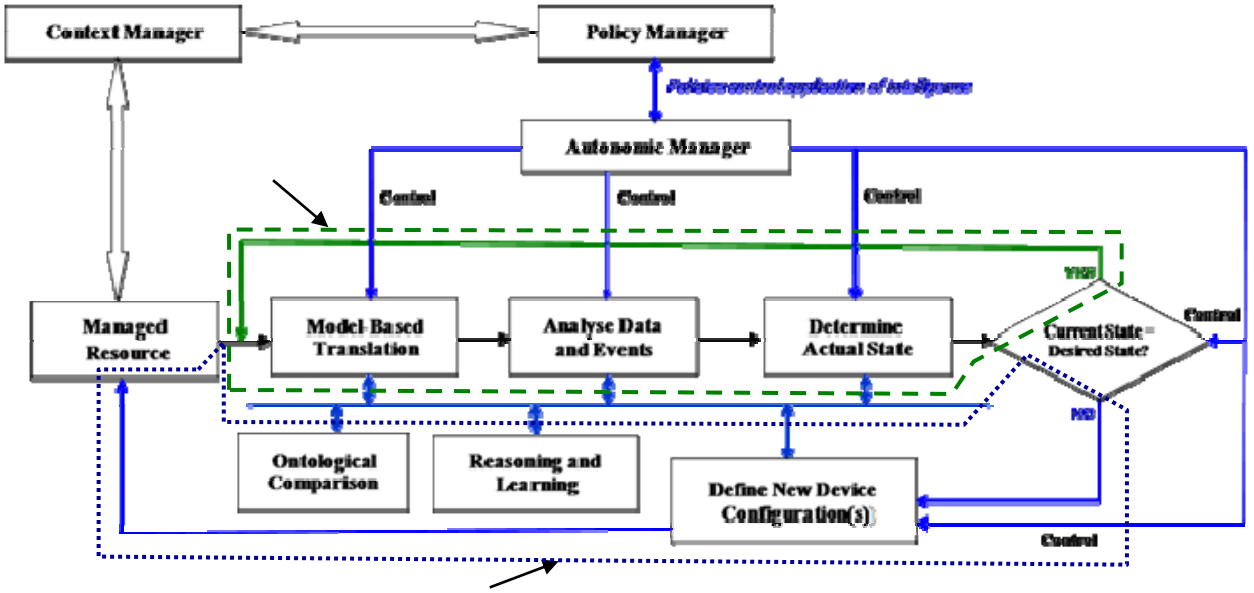
Research Efforts in the US – FIND Projects

- Model-based diagnosis in the Knowledge Plane
  - Agent architecture: decomposition of the knowledge-based diagnosis problem into a multi-agent architecture.
  - Knowledge representation: development of an initial ontology for KP-based diagnosis problems
  - Knowledge routing and management of partial information: consideration of a knowledge routing architecture

- A Network-Wide Hashing Infrastructure for Measurement and Monitoring
  - What types of measurement and monitoring tasks have effective solutions based on hashing?
  - What types of hashing data structures are most efficient for these tasks?
  - What would be the best form for the underlying hardware and architecture for a general-purpose network hashing infrastructure?
  - How can this infrastructure be made to universal among network devices, and what power would this give for network-level monitoring tasks?
  - What type of language, control structures, and hashing primitives should users have to leverage this type of architecture most effectively?
  - Objective:
    - Provide intrinsic capability of self-measurement and self-monitoring
    - Provide simple, flexible, cost-effective hash-based management infrastructure

Research Efforts in the US – FOCALE

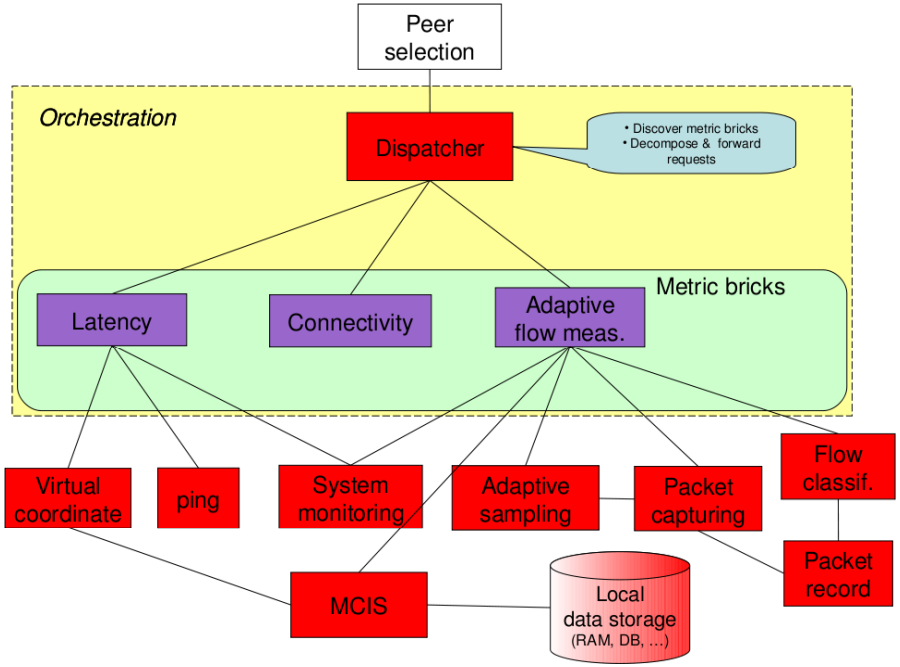


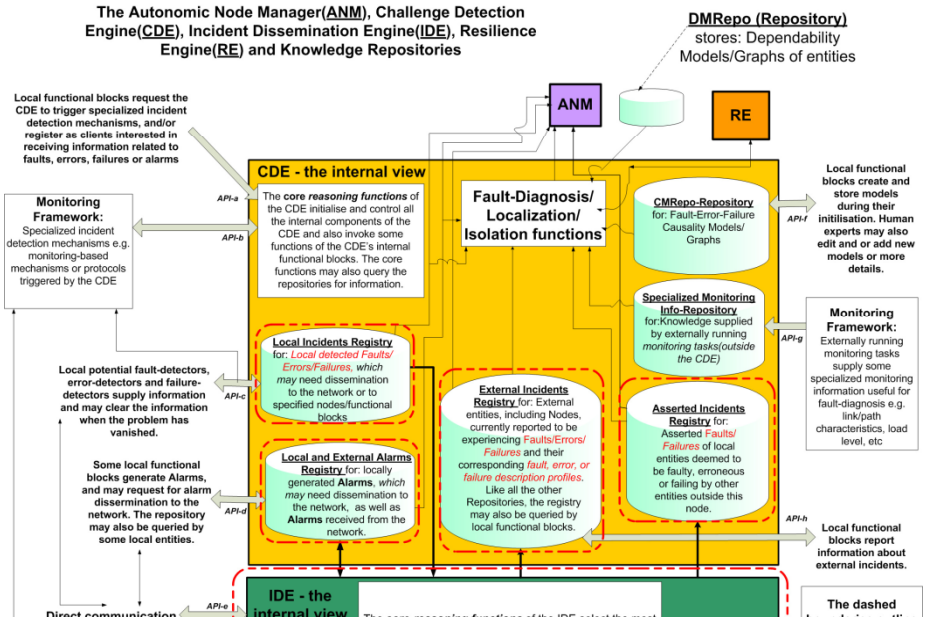


Research Efforts in Europe – FP7/ANA

ANA (Autonomic Network Architecture)

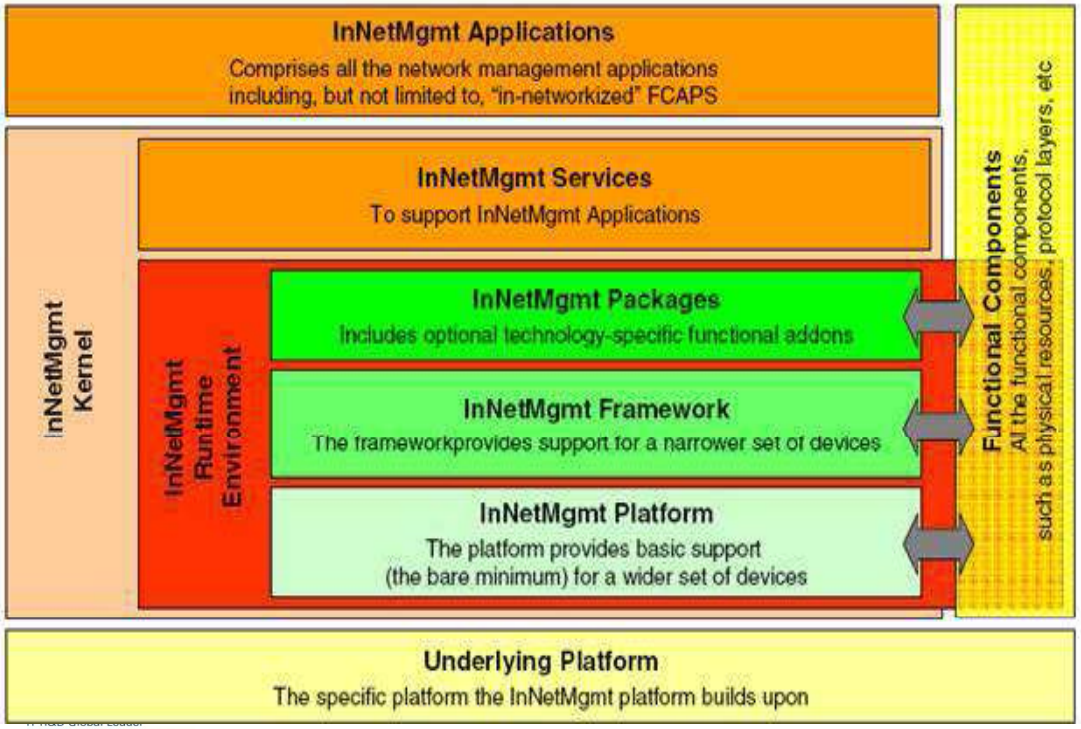
- a networking architecture composed of self-configuring nodes, self-organizing into a network system through neighbor interactions, with multiple such systems self-federating into a heterogeneous Internetwork
- Apart from these, the networking systems should possess the properties of self-protection and self healing
- For management, self-monitoring and self-fault detection and management

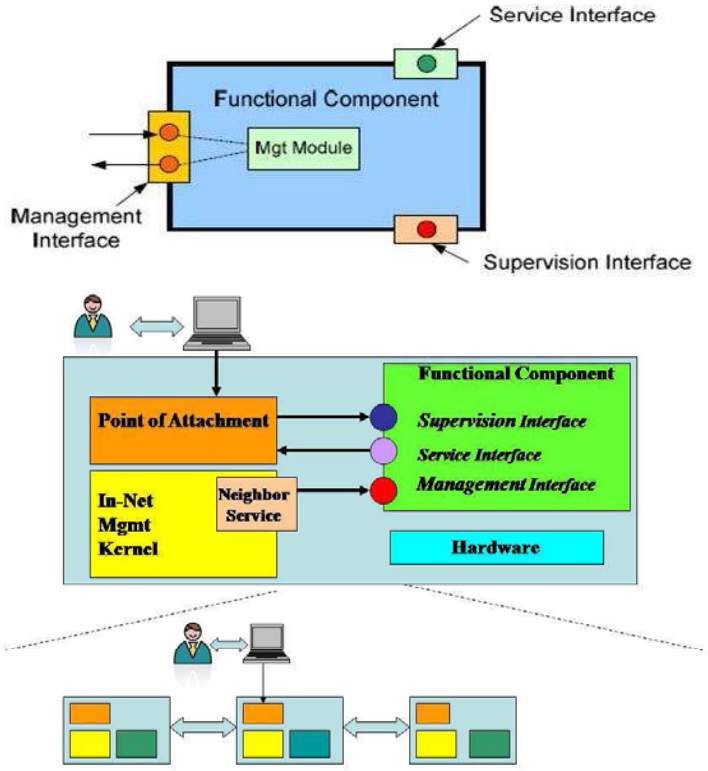




Research Efforts in Europe – FP7/4WARD

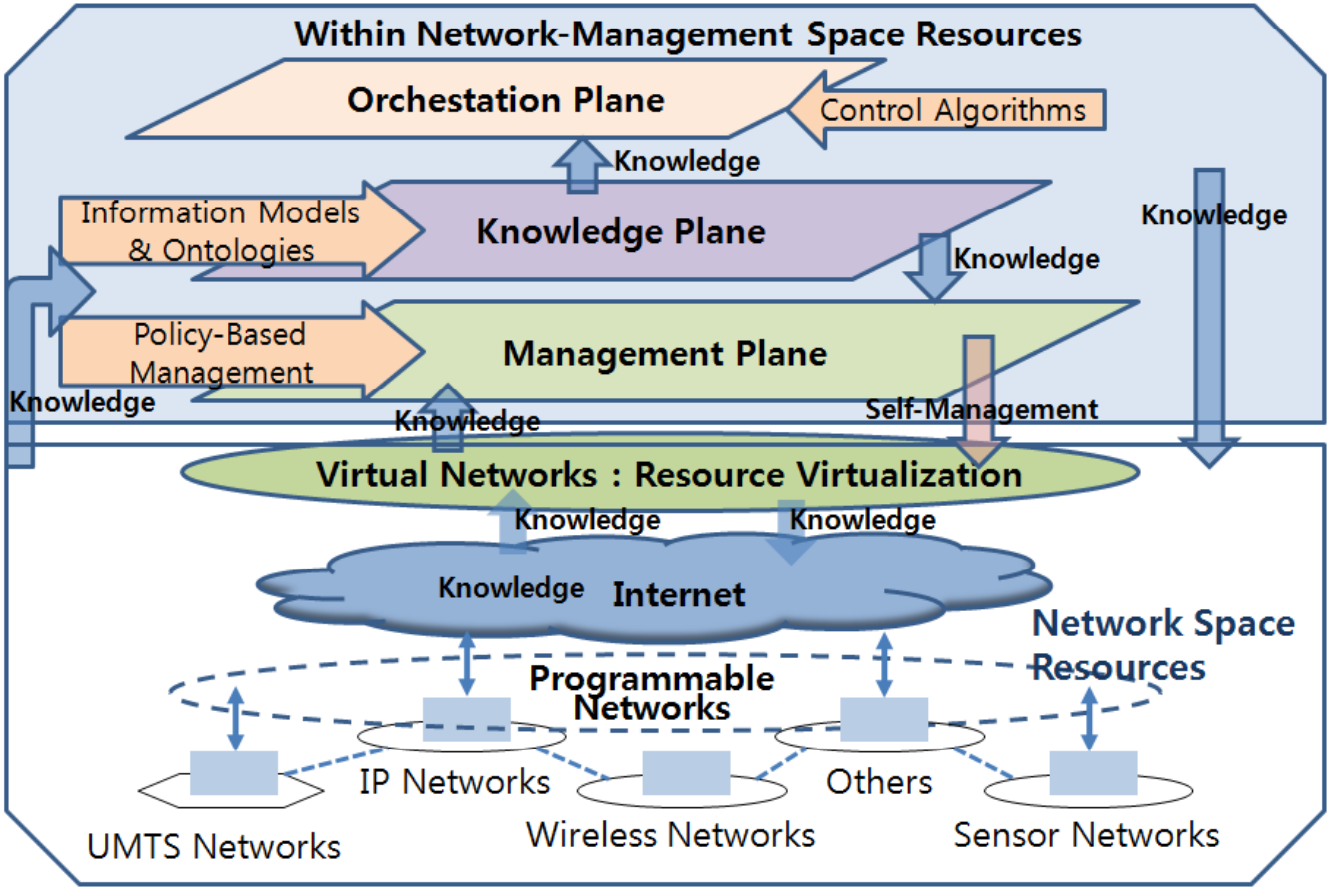
- **INM (In-Network Management)**
  - management functionalities are embedded into every network nodes unlike centralized approaches such as 4D, CONMan, Mastro
  - (1) Inherent: Management capability inseparable from the logic of the logic of the component (TCP congestion control),
  - (2) Integrated: Management capability internal to a functional component but separable from the component logic, and
  - (3)External: Management capability located on another node.





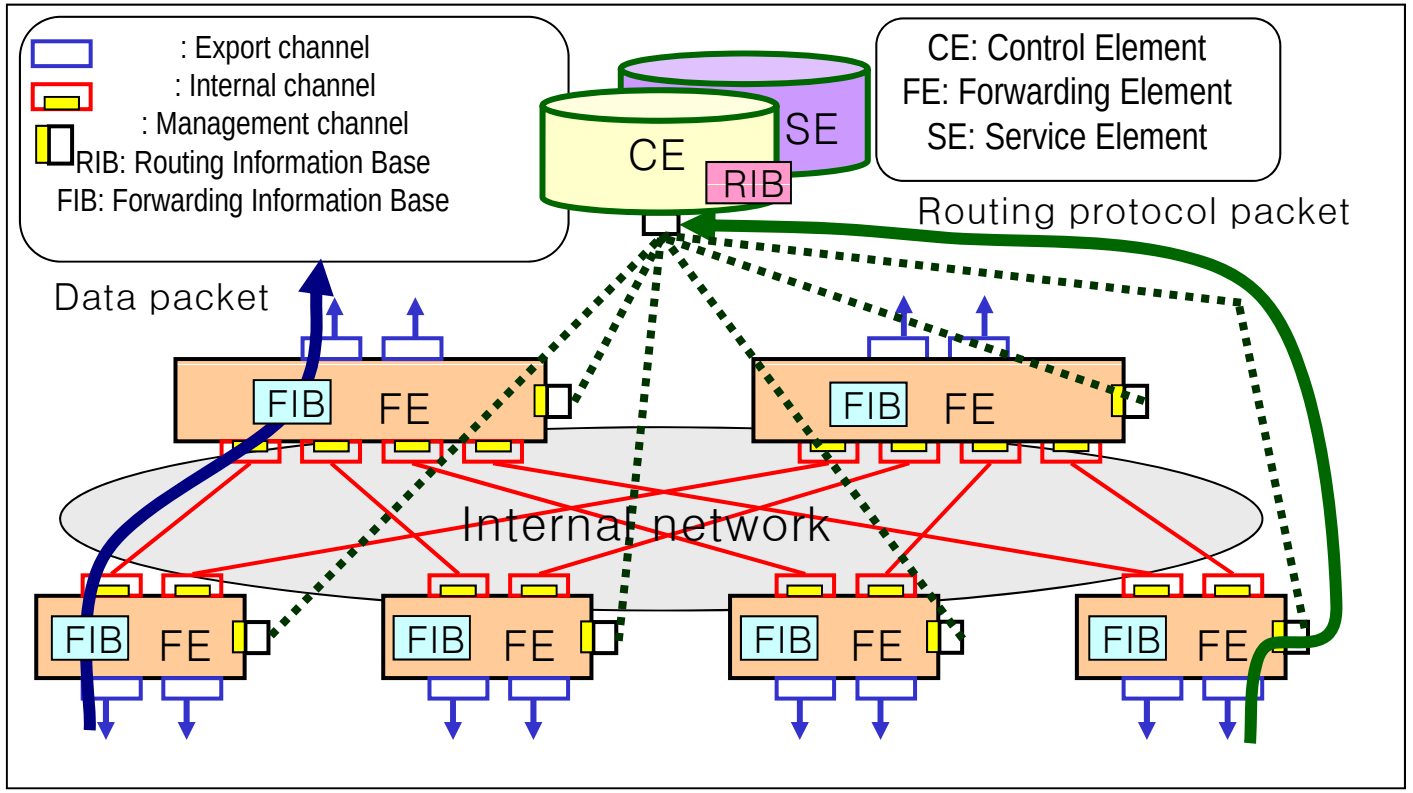
Research Efforts in Europe – Autol

- Autol
  - Objectives to develop self-managing virtual resources
  - Autonomic management extended based on FOCALE
  - Guarantee virtualization, security, reliablity, robustness, mobility, context, heterogeneous access, and multi-domains



Research Efforts in Japan – NTT

- **Funtcionally Distributed Network Architecture**
  - Easy to build large-scale network
  - Becomes easy to debug program
  - Becomes easy to add new functions
  - Becomes easy to control path



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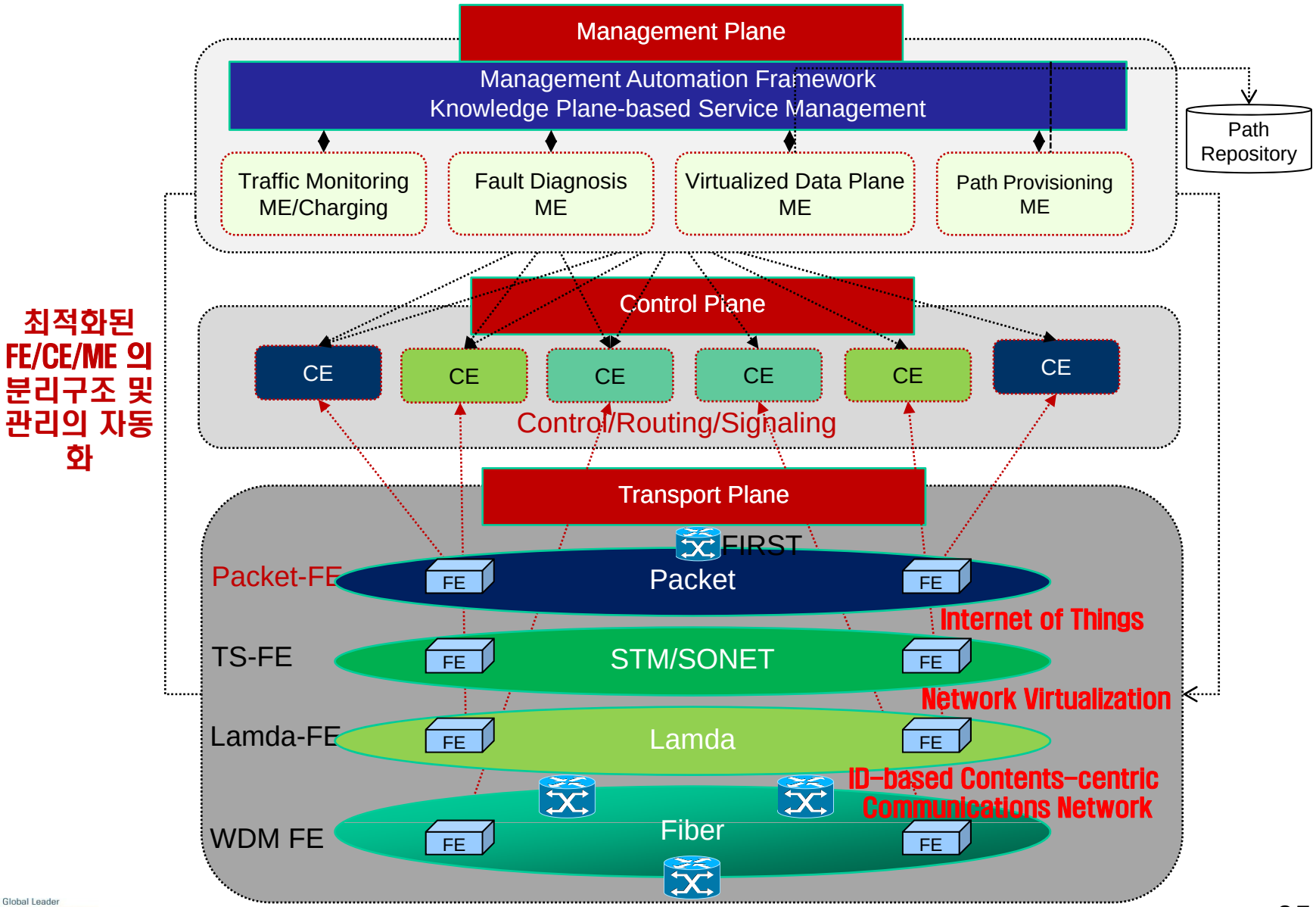
- **A Way Forward: Our Approach**

Our Approach: HiMang – Main Objectives

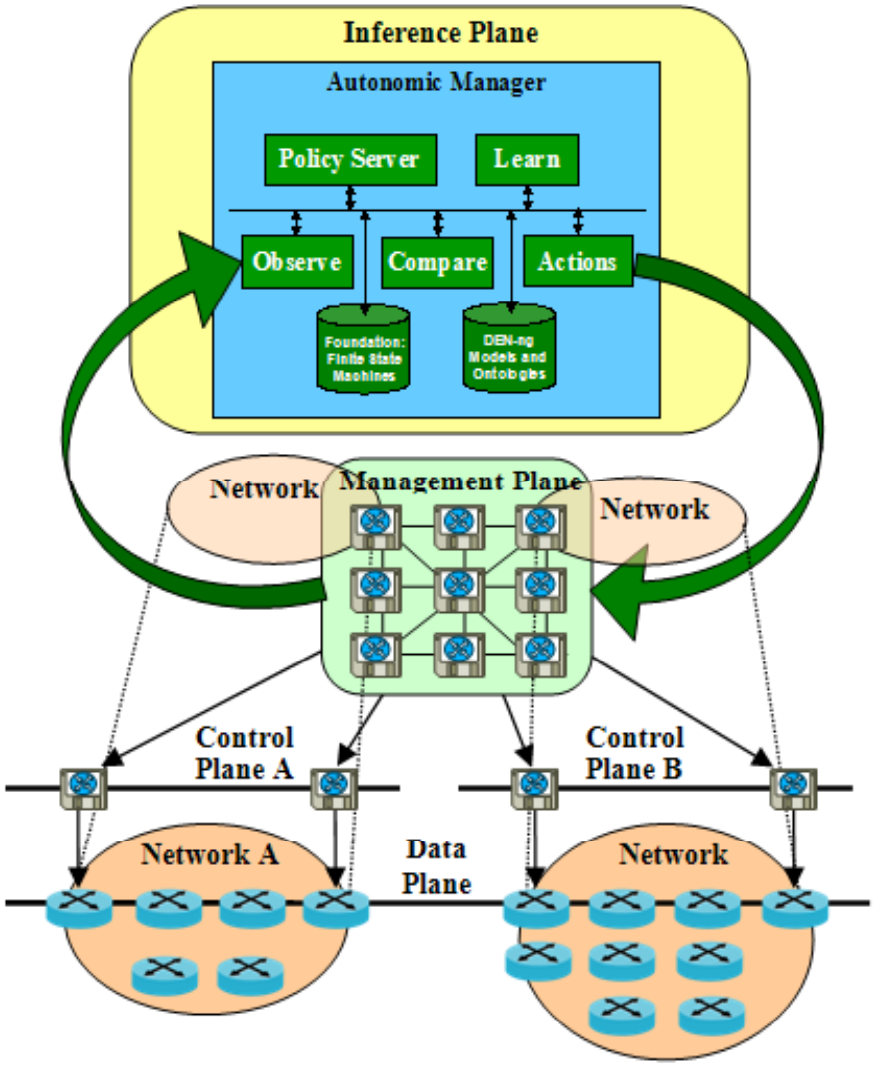
- Design of Highly Manageable Network and service management architecture for New Generation (HiMang)
  - which has reliability, scalability, accuracy, mobility, economic feasibility, and self–* properties of Future Internet infrastructure and development of original core technology and research prototype
- Separation of data, control, and management planes
- Virtualized data plane management architecture implementation
- Traffic measurement and analysis
- Fault detection, diagnosis, isolation, and remediation
- Knowledge plane based network/service management architecture

Our Management Architecture for FI



최적화된 FE/CE/ME 의 분리구조 및 관리의 자동화

Inference Plane: Conceptual Overview



Layered Management Models for Semantic Routing